Laboratory AE simulation of the transition between VT and LP events in active volcanoes

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Outline

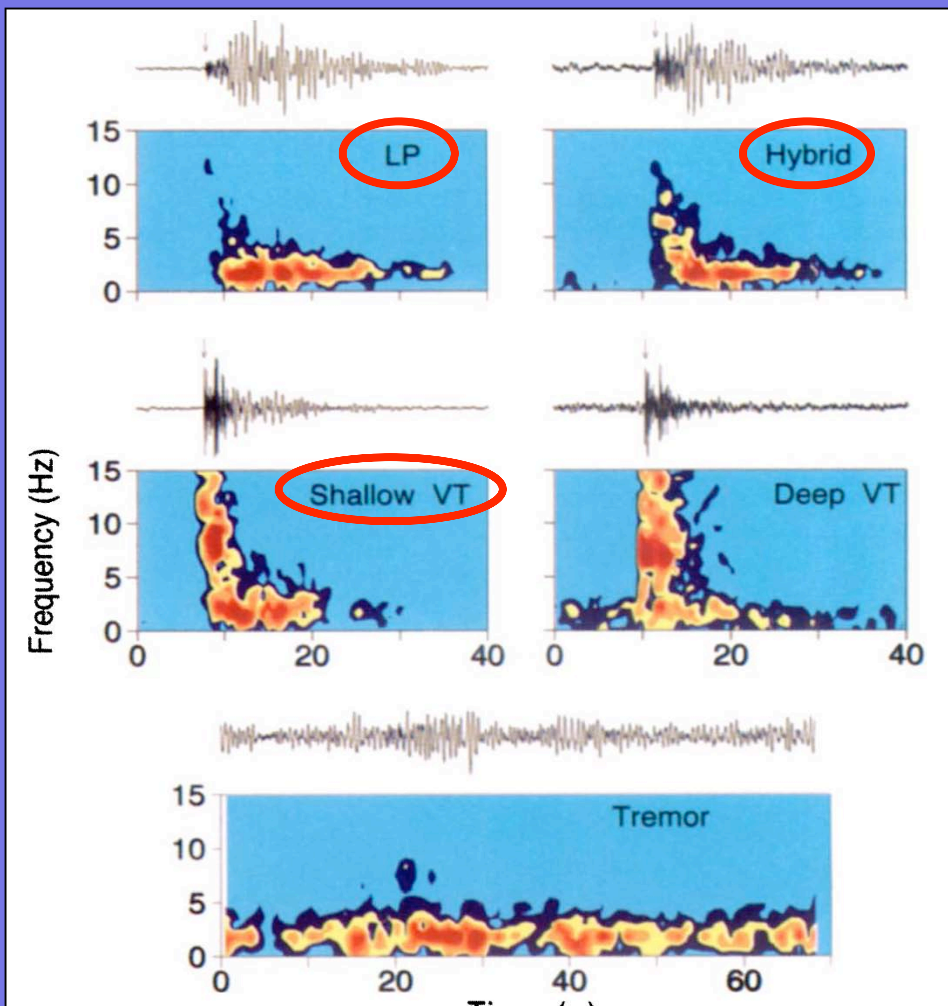
Laboratory triaxial deformation of Etna Basalt:

1. **Acoustic emission (AE) location of the evolving faults**
2. **After the deformation stage, the fault is rapidly decompressed to stimulate 'low' frequency events: Location**
3. **Frequency analysis and comparisons between these lab events and field data.**
4. **Work in progress - advanced analysis (mechanisms)**

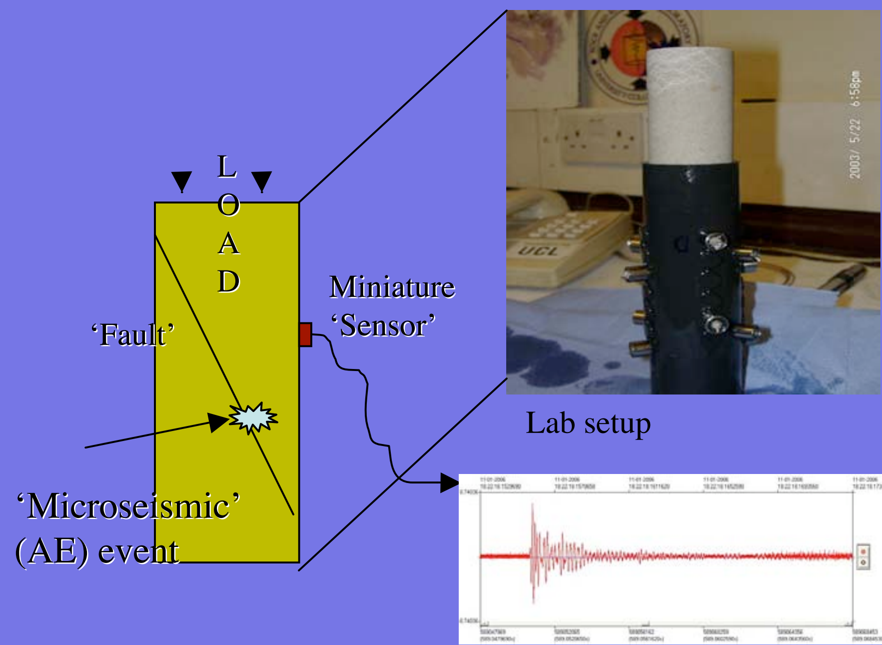
The pride and joy! Our new testing machine at the University of Toronto!

Introduction: Field data examples & Low frequency events

- The Issue: Seismicity is a key method for monitoring active volcanoes…
- This, usefully, is easily measured in the laboratory (AE) during <u>controlled</u> deformation testing

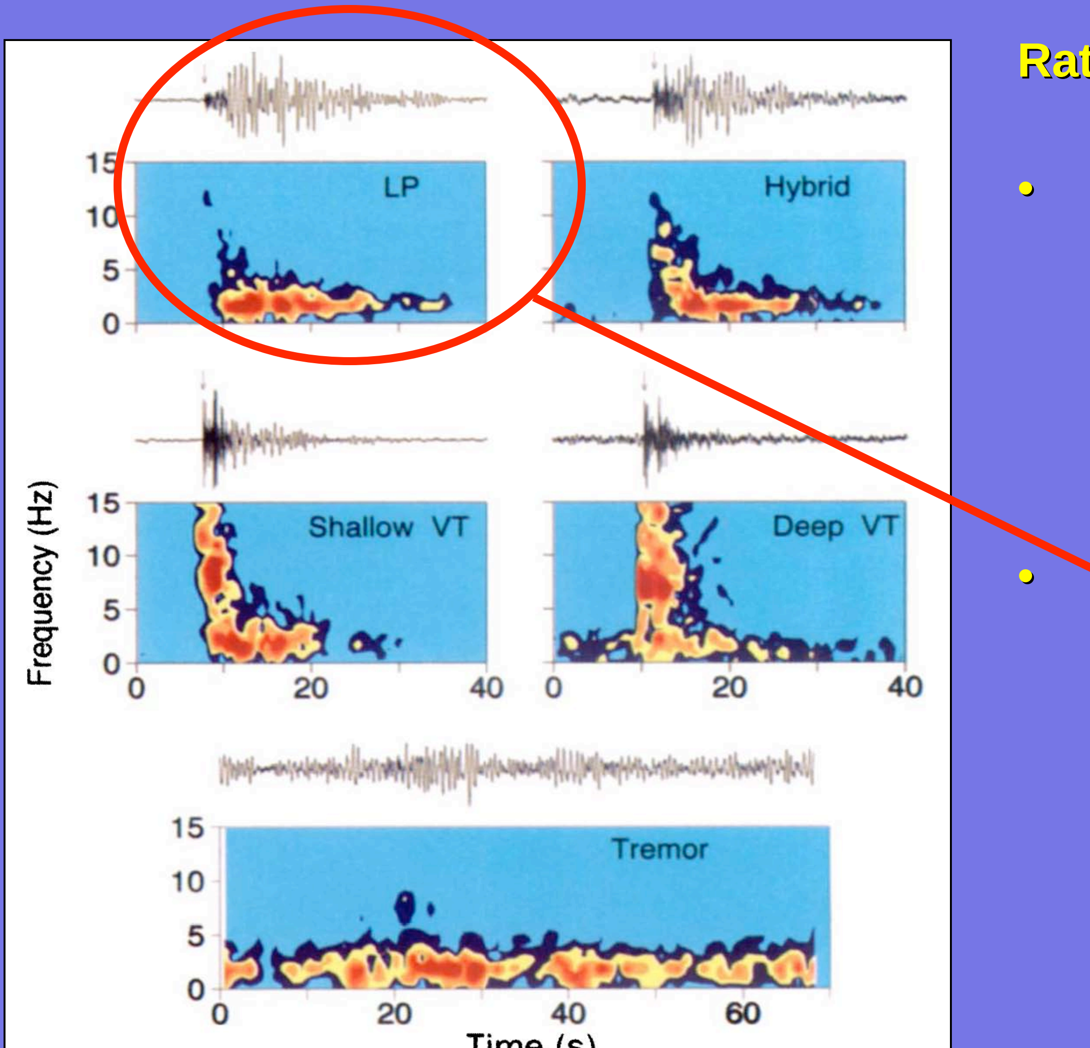


Chouet, 1996, Nature



A variety of seismic events types are seen, from Volcano tectonic (VT) indicative of brittle failure to Low frequency events (LF) that are indicative of fluid movement within cracks and fractures.

Introduction: Field data examples & Low frequency events



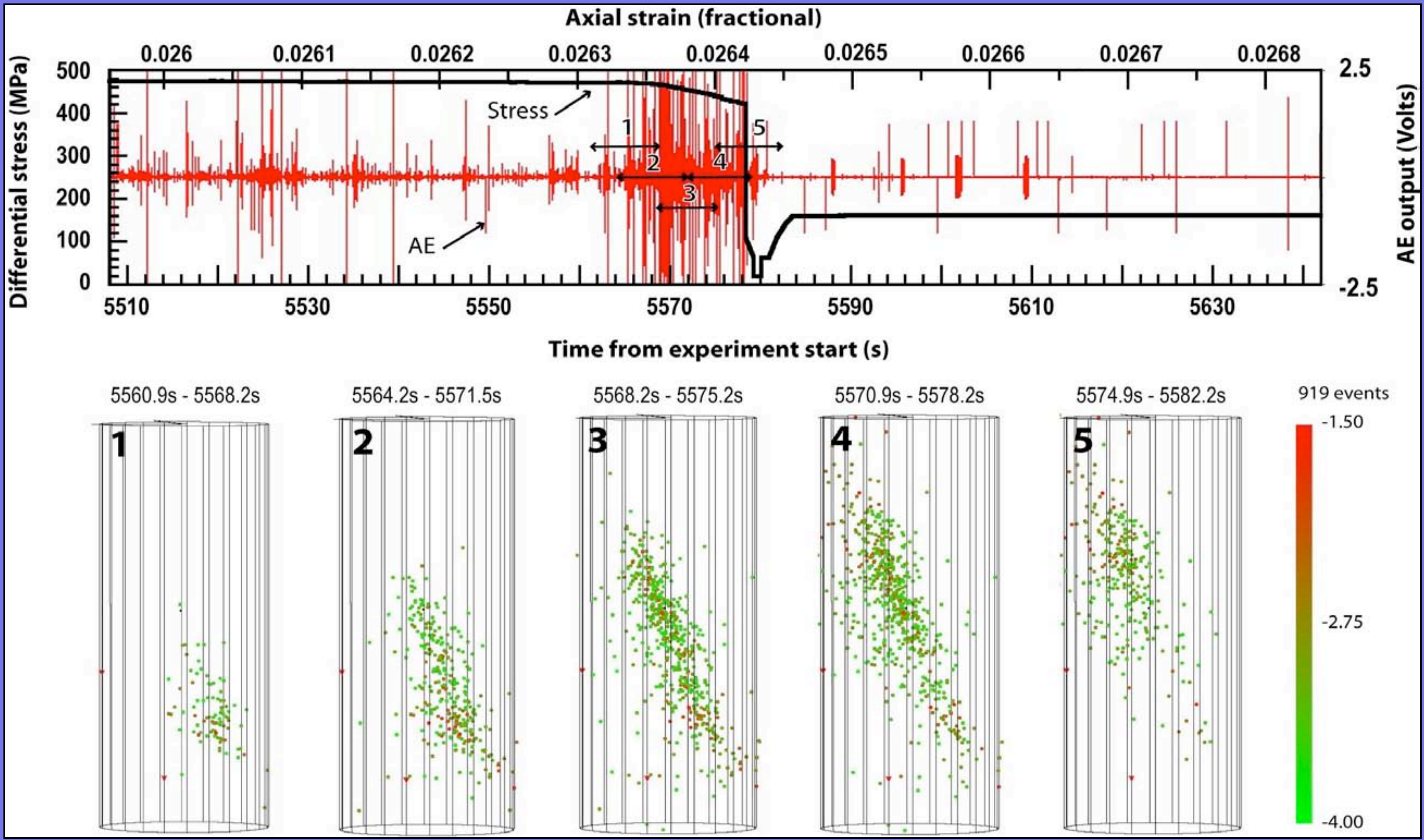
Chouet, 1996, Nature

Rationale:

- **Prediction of volcanic unrest is difficult: However, eruptions are often preceded by increasing duration and instances of low frequency events**
- **The primary focus of this research is therefore to attempt to reproduce LF events in the laboratory using triaxial deformation and rock physics methods: in order to control and explore the physics of such events**

Previous work

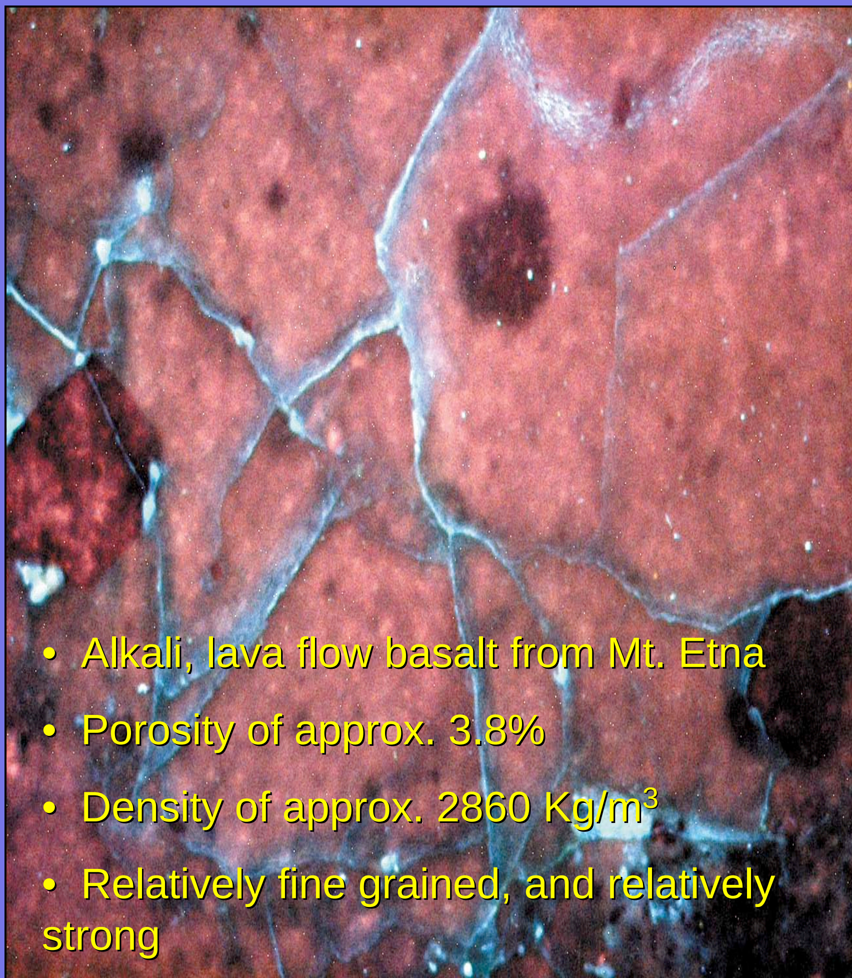
- Prior work used Etna basalt (isotropic crack fabric) under triaxial deformation
- Decompressions, however, are scarce and not locateable
- So design new experiment with direct access



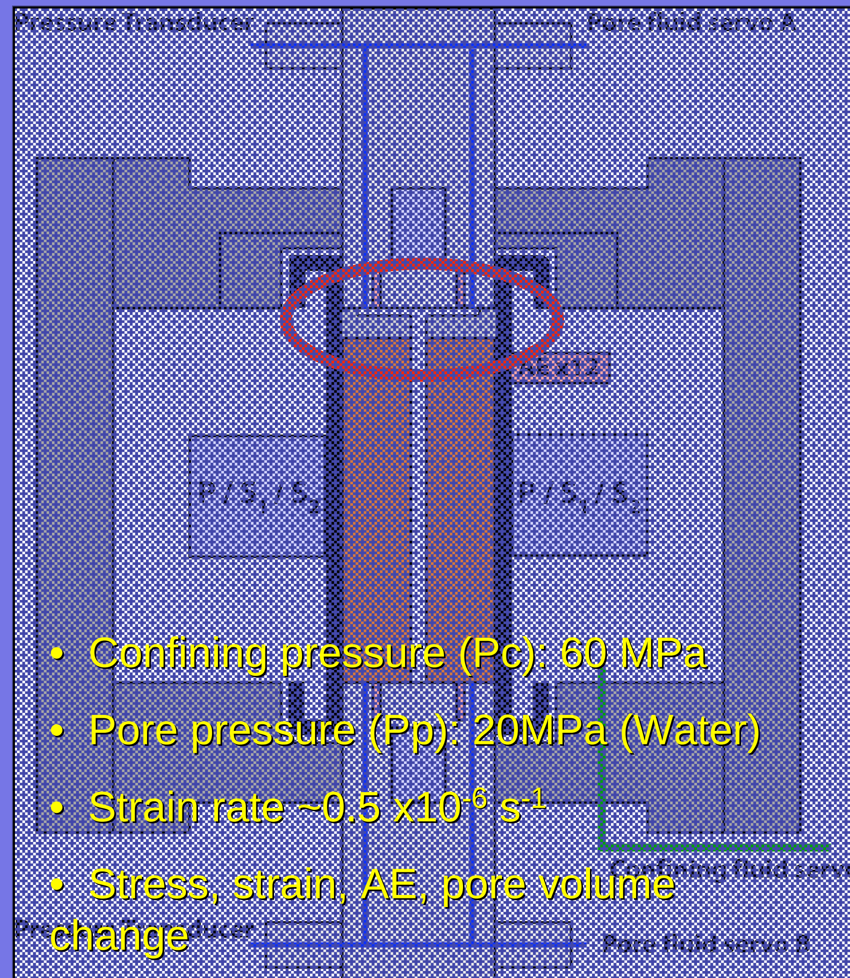
Benson et al., 2007, GRL

Experimental setup

- Advanced, instrumented Hoek cell (Elastic wave velocities, AE, permeability)



- Alkali, lava flow basalt from Mt. Etna
- Porosity of approx. 3.8%
- Density of approx. 2860 Kg/m^3
- Relatively fine grained, and relatively strong



- Confining pressure (Pc): 60 MPa
- Pore pressure (Pp): 20MPa (Water)
- Strain rate ~0.5 $x10^{-6}$ s^{-1}
- Stress, strain, AE, pore volume change

Mechanical response of Etna basalt

- Confining pressure (Pc): 60 MPa
- Pore pressure (Pp): 20MPa (Water)
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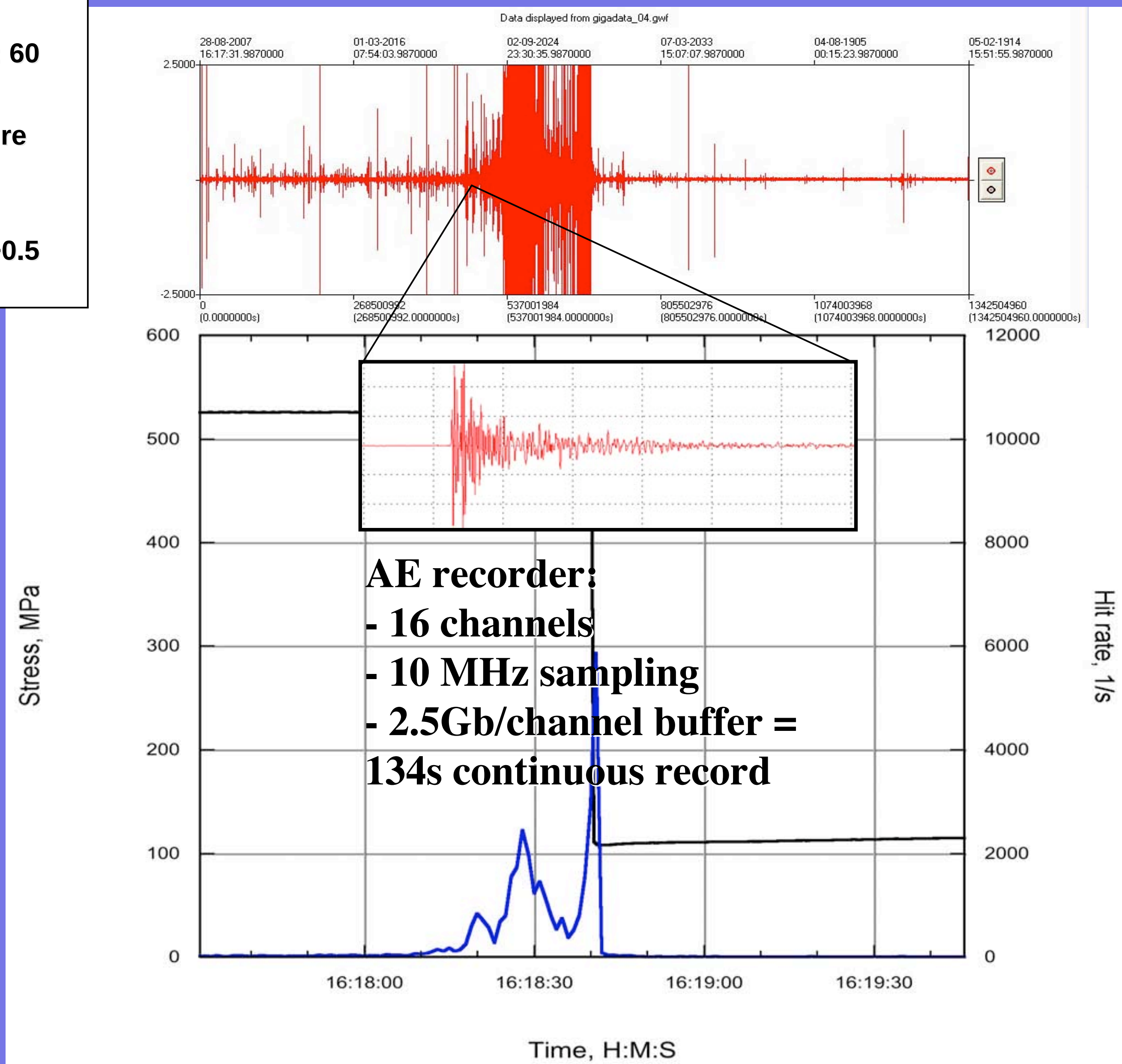
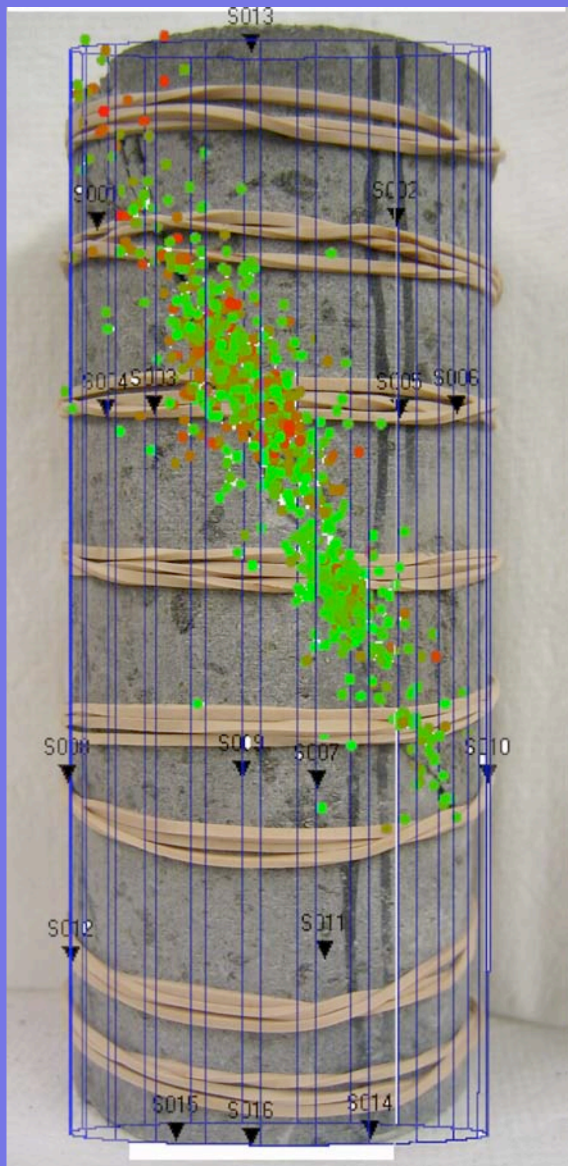
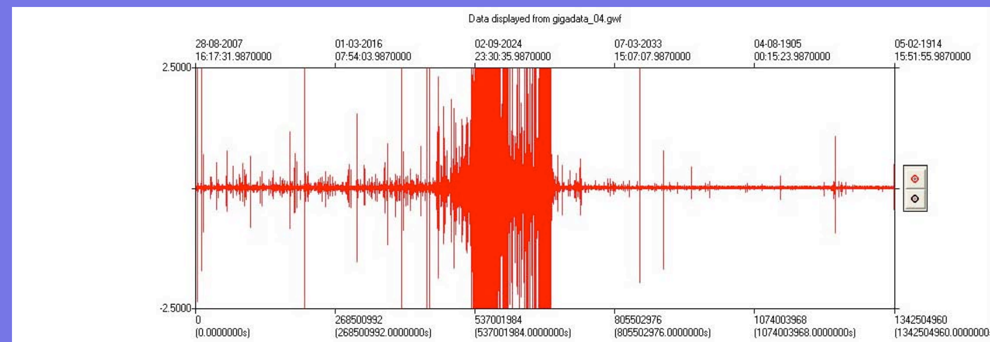
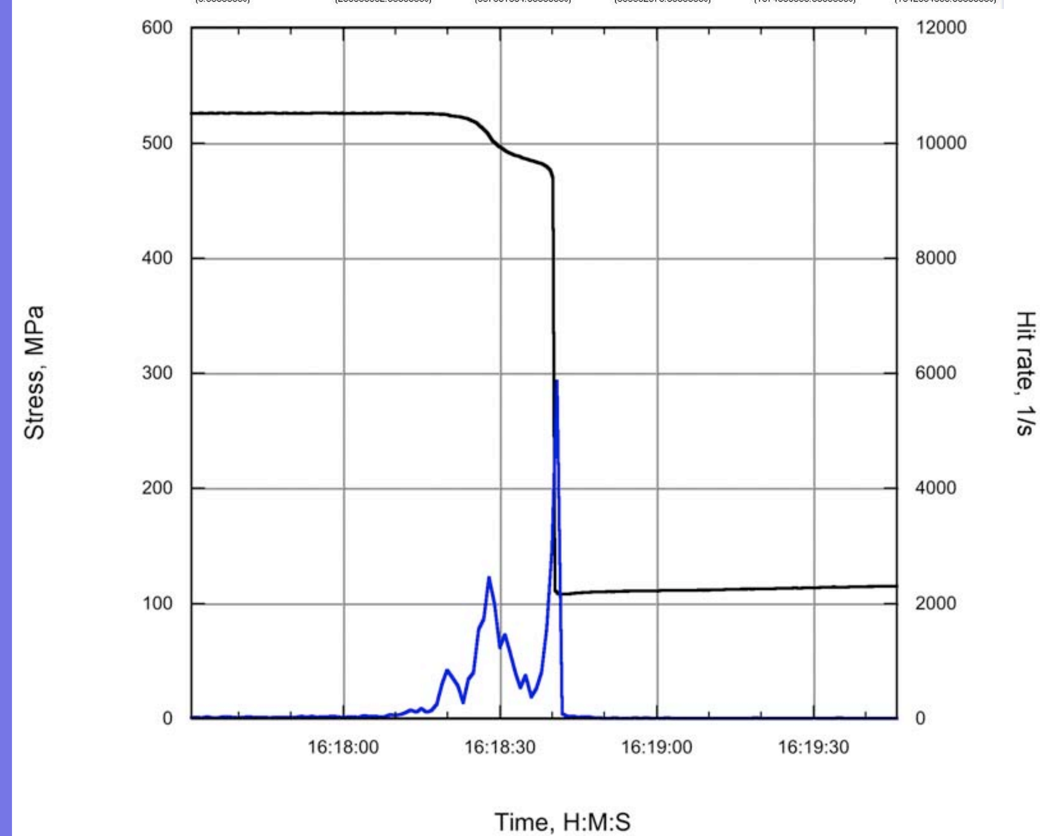


Stage 1: AE location of a developing fault

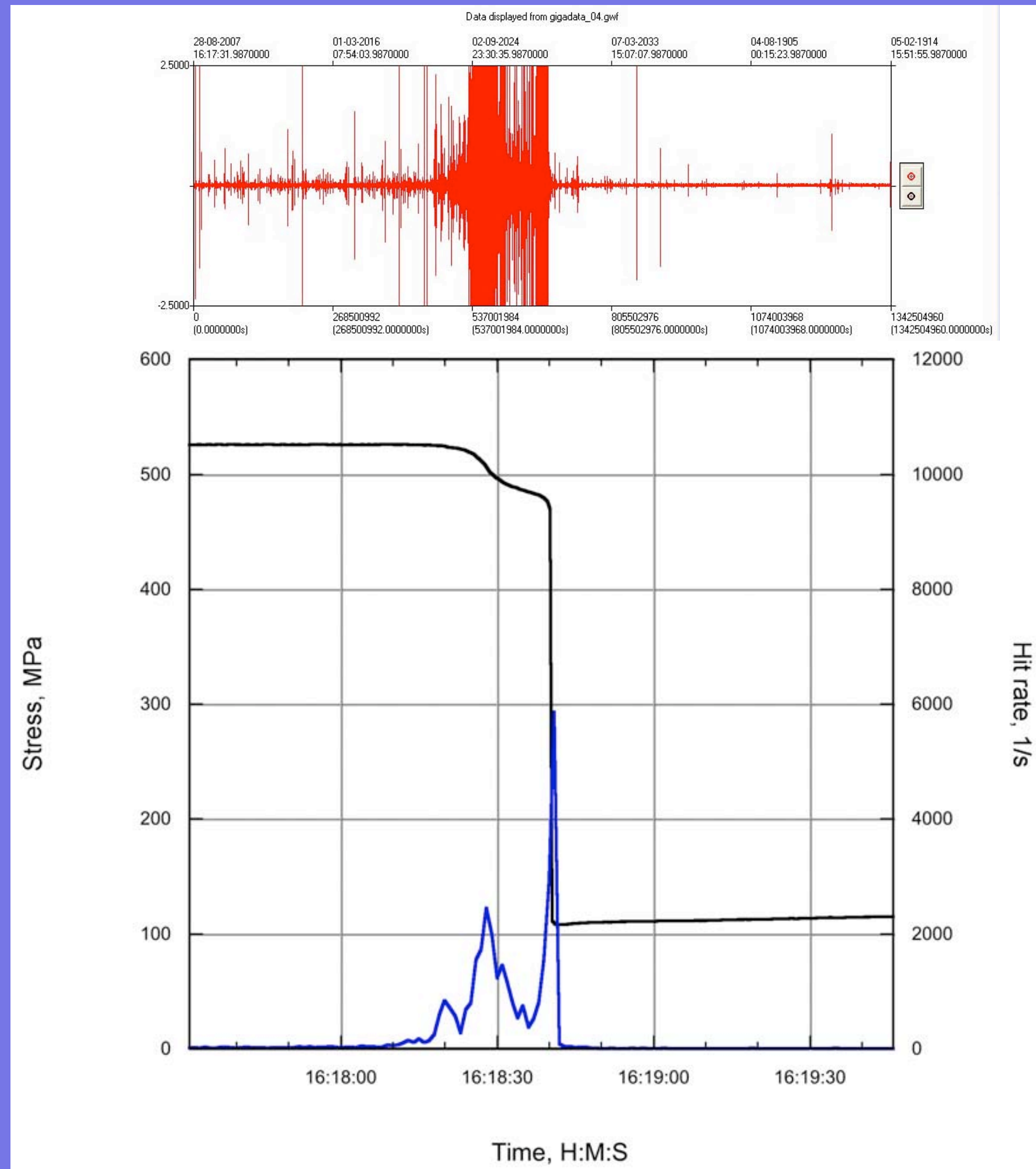






P.M. Benson, Euro-Conference, Erice, 2007

AE location of developing fault (brittle): movie 1



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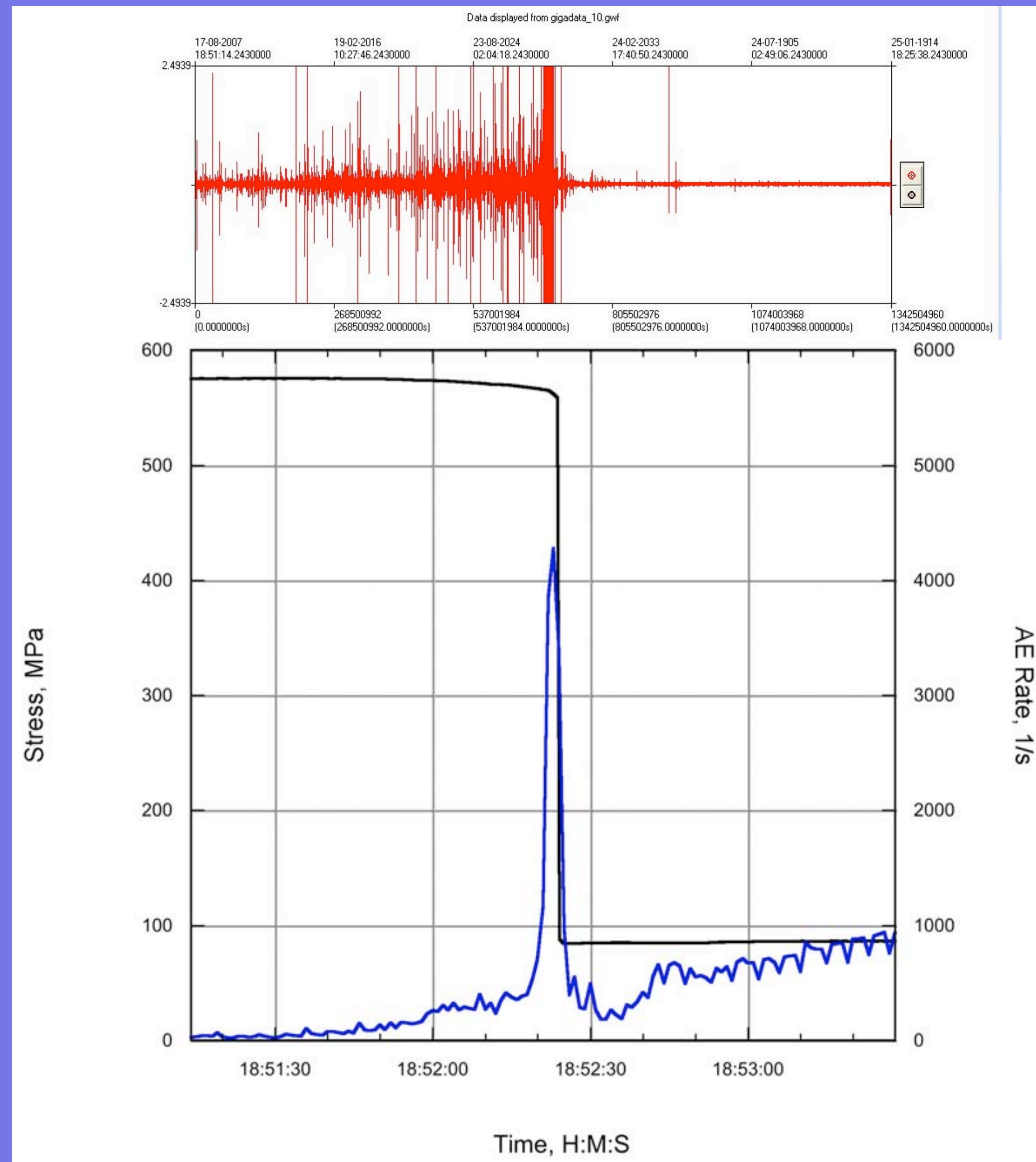
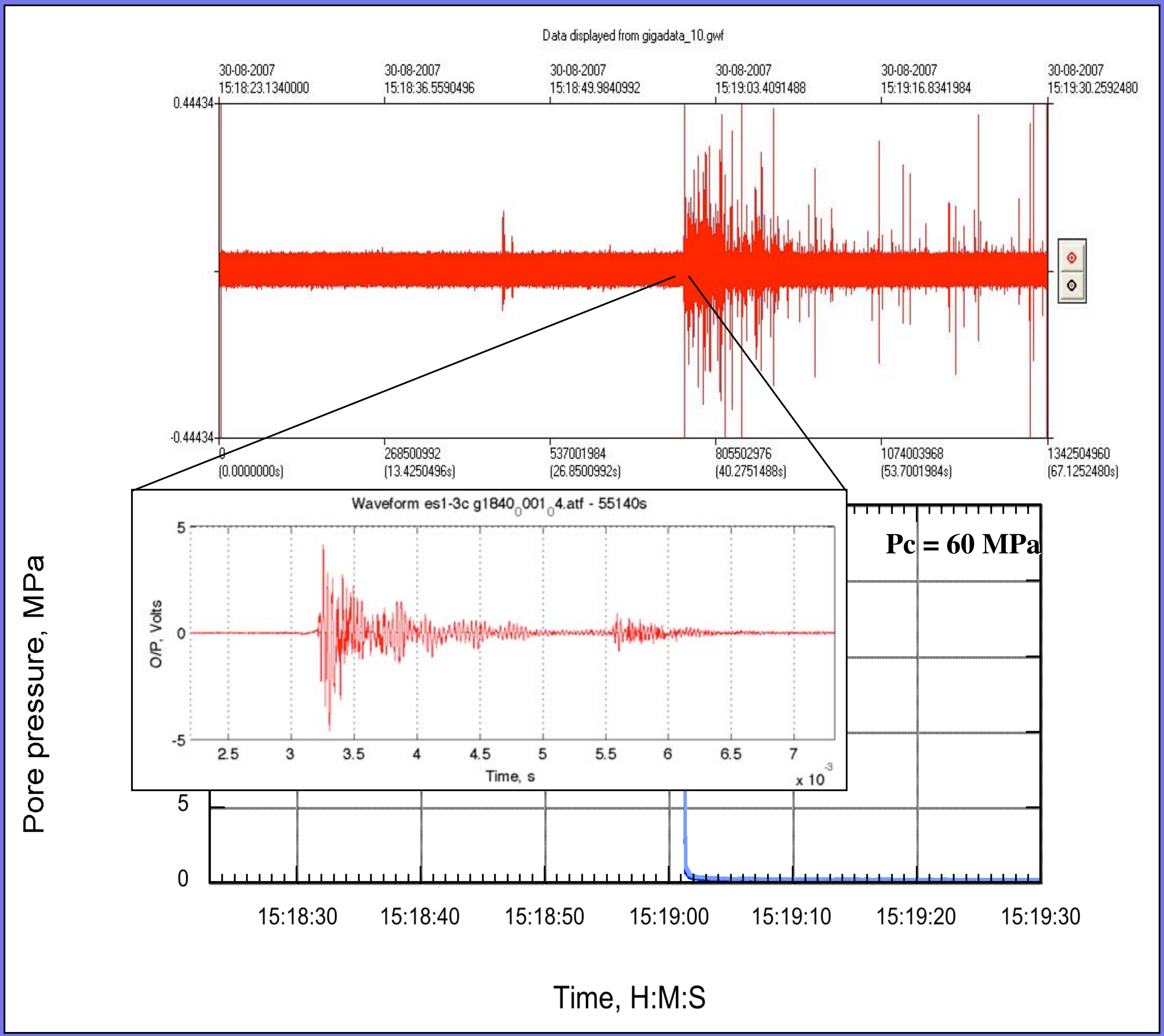
AE location of developing fault (brittle): movie 2



Stage 2: Decompressing the (located) fault zone

- After brittle deformation (failure) of the sample, the pore space is rapidly decompressed from the top of the sample
- This obviously includes the fault previously located by the AE location method
- The conduit provides direct access to the damage zone
- A 'swarm' of AE activity is recorded



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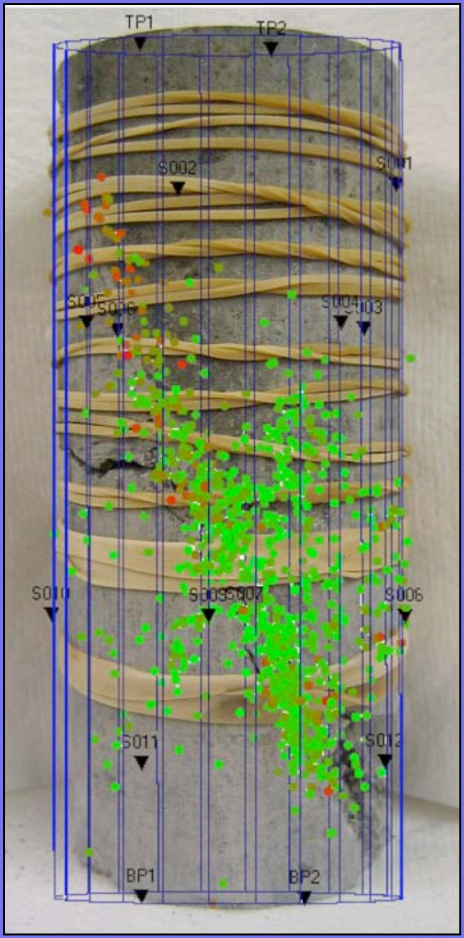
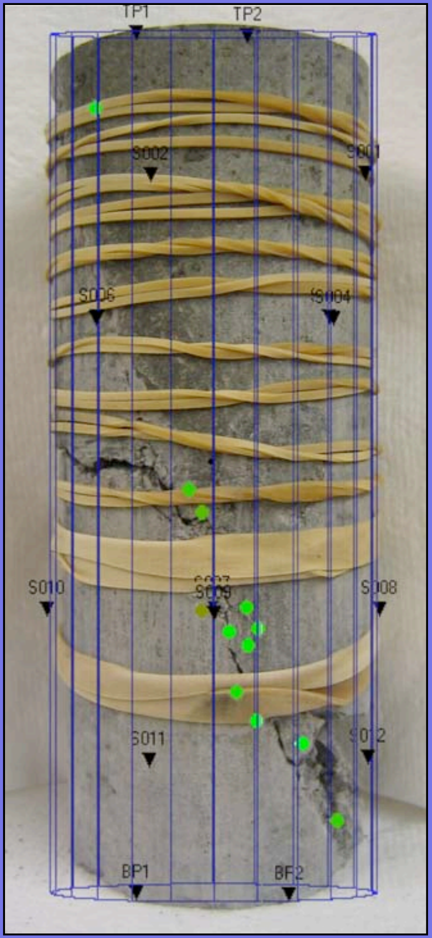
Analysis: Location of decompression events

- Locating brittle deformation events is reasonably easy
- However, the events created due to decompressing the damage zone are much more emergent - with a lower frequency - than brittle events. Picking these accurately is a challenge….





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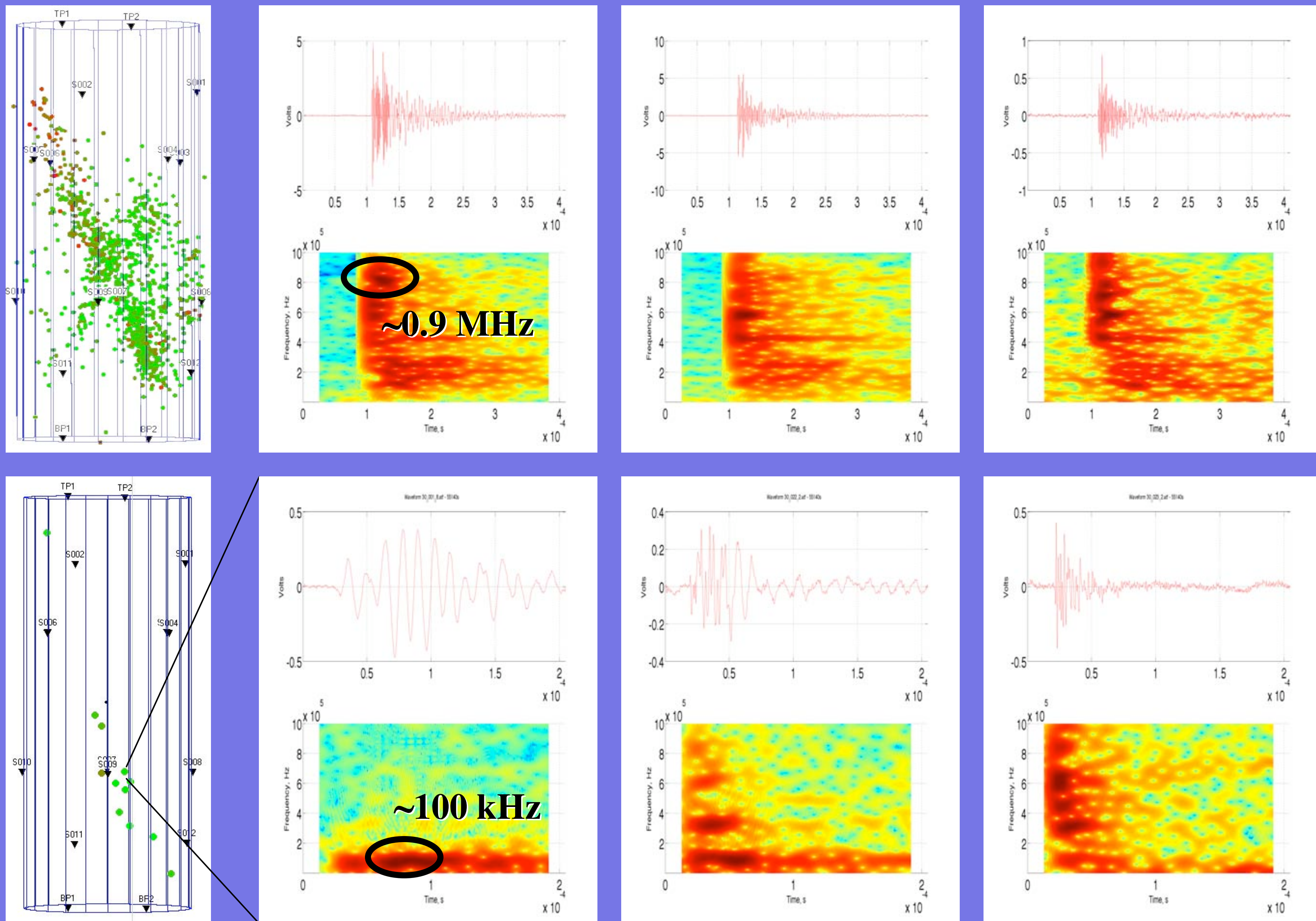
Frequency changes

BRITTLE

DECOMPRESSION



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Frequency comparisons: VT/LF

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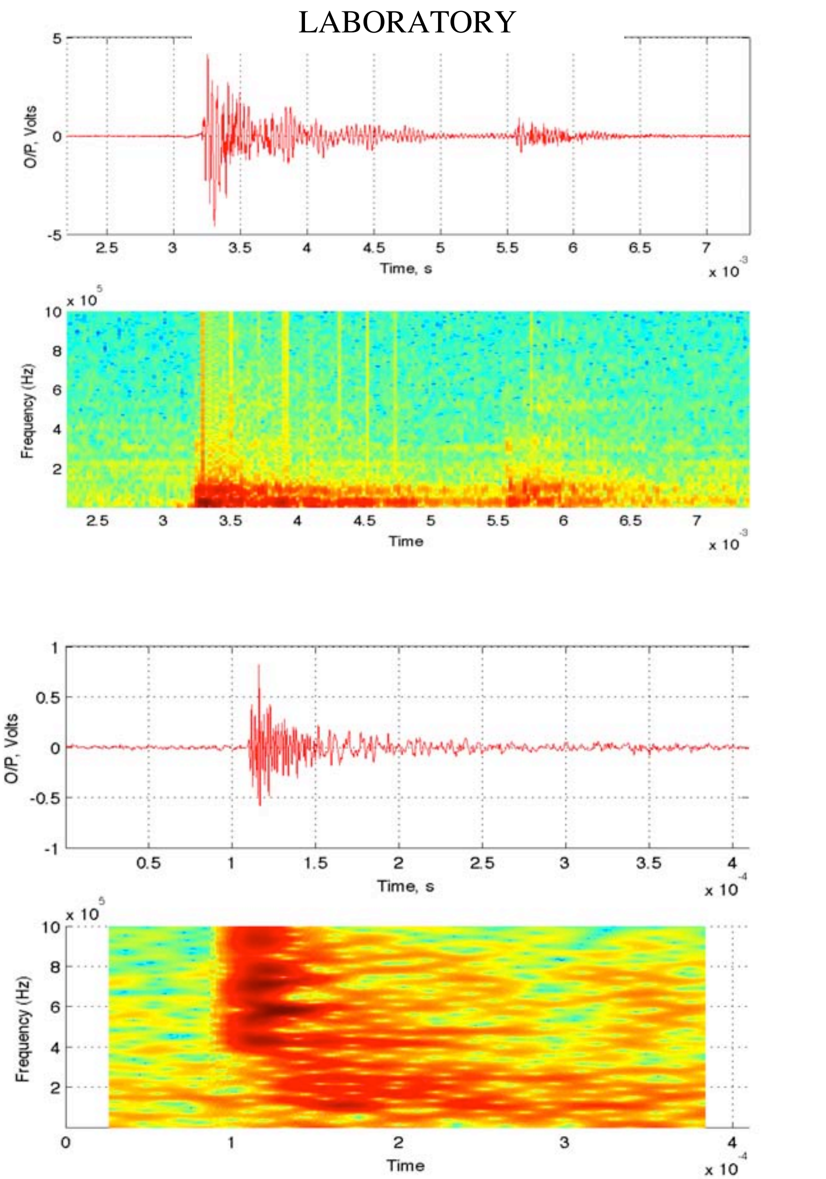

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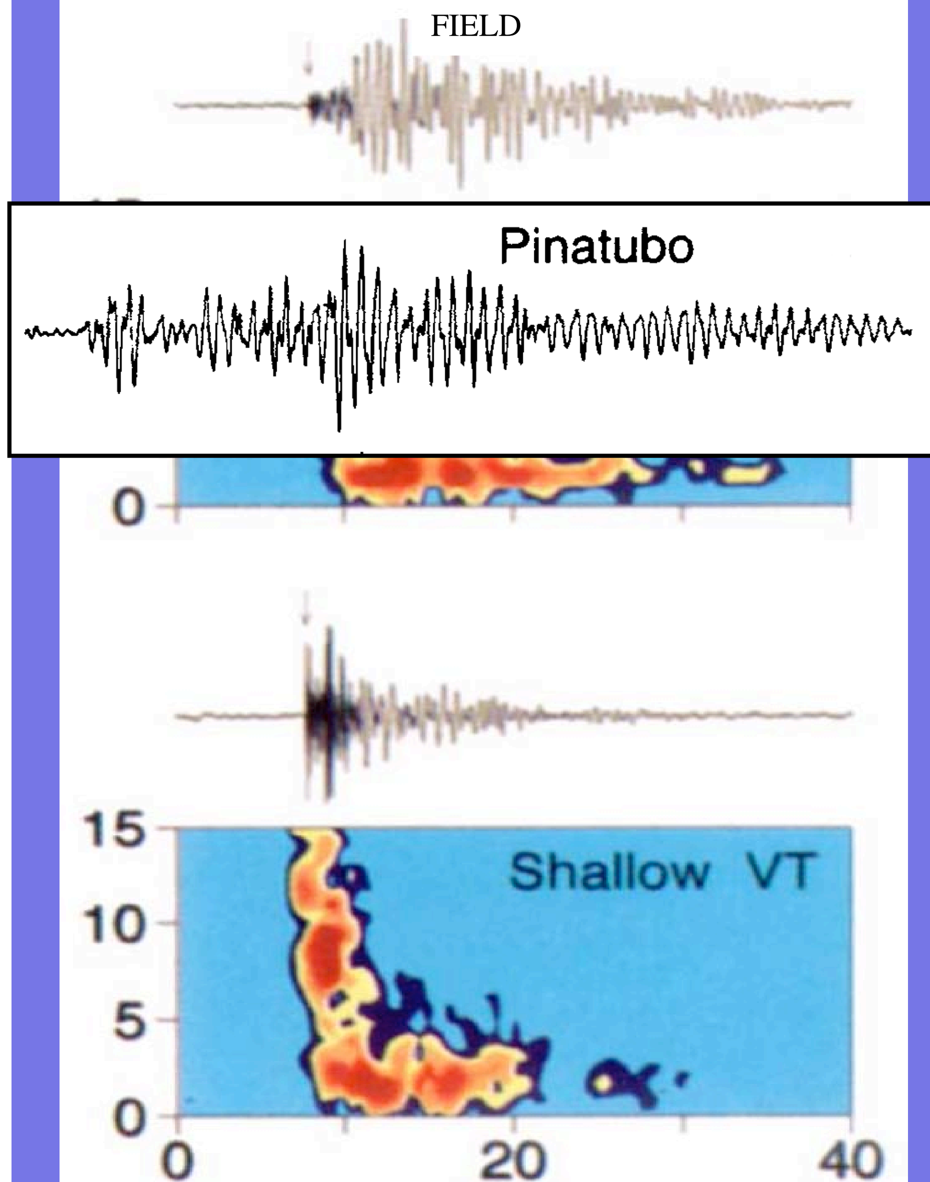
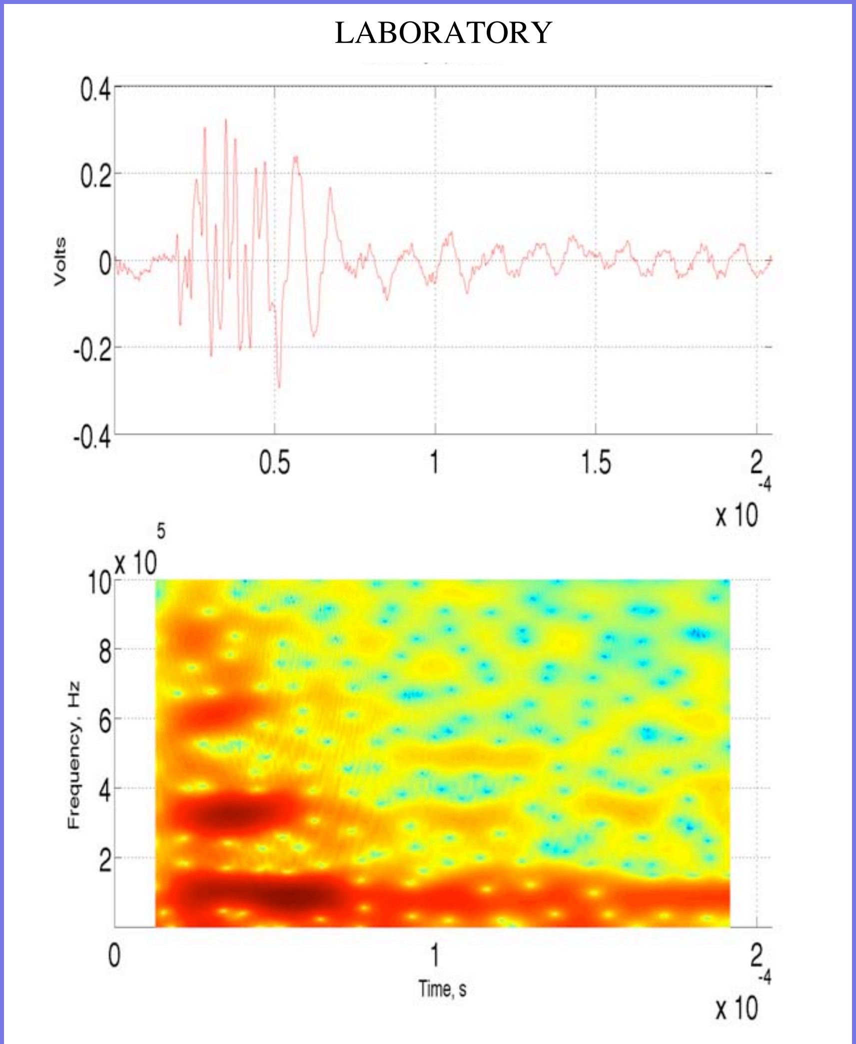
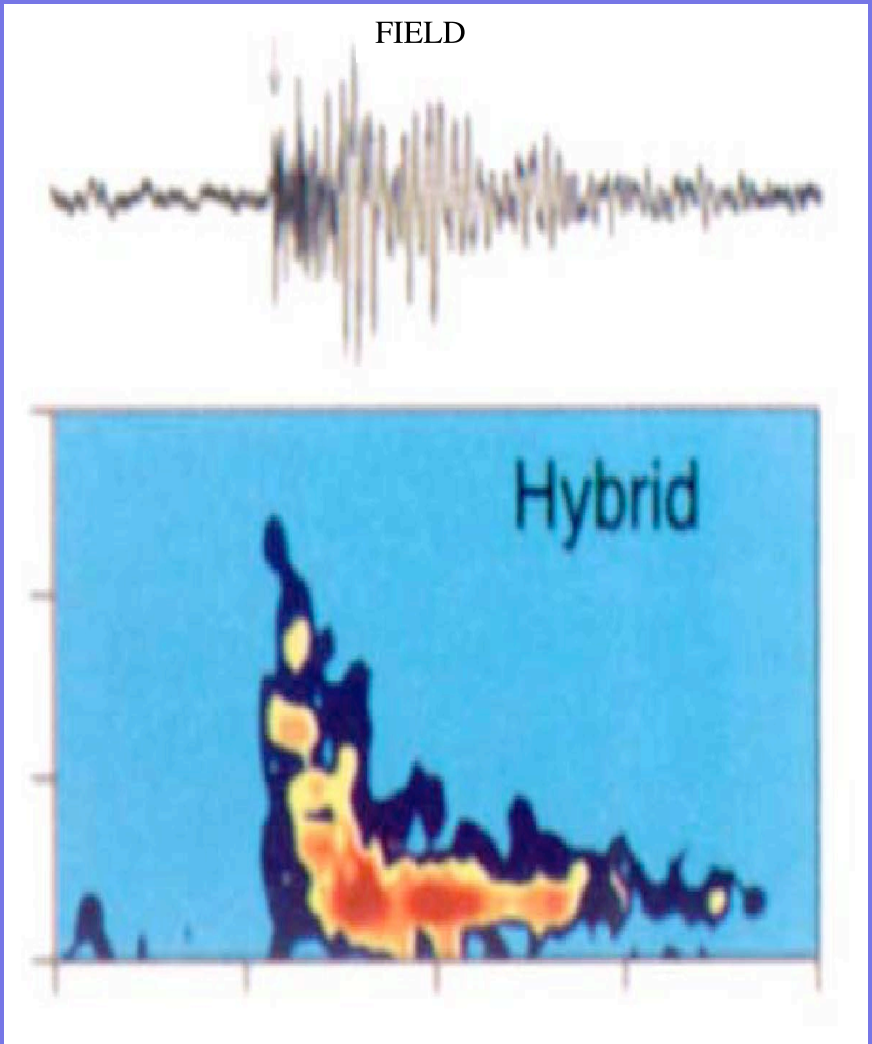


Chouet, 1996, Nature

P.M. Benson, Euro-Conference, Erice, 2007

Frequency comparisons: hybrid





Chouet, 1996, Nature

Discussion of physical processes during decompression events: work in progress

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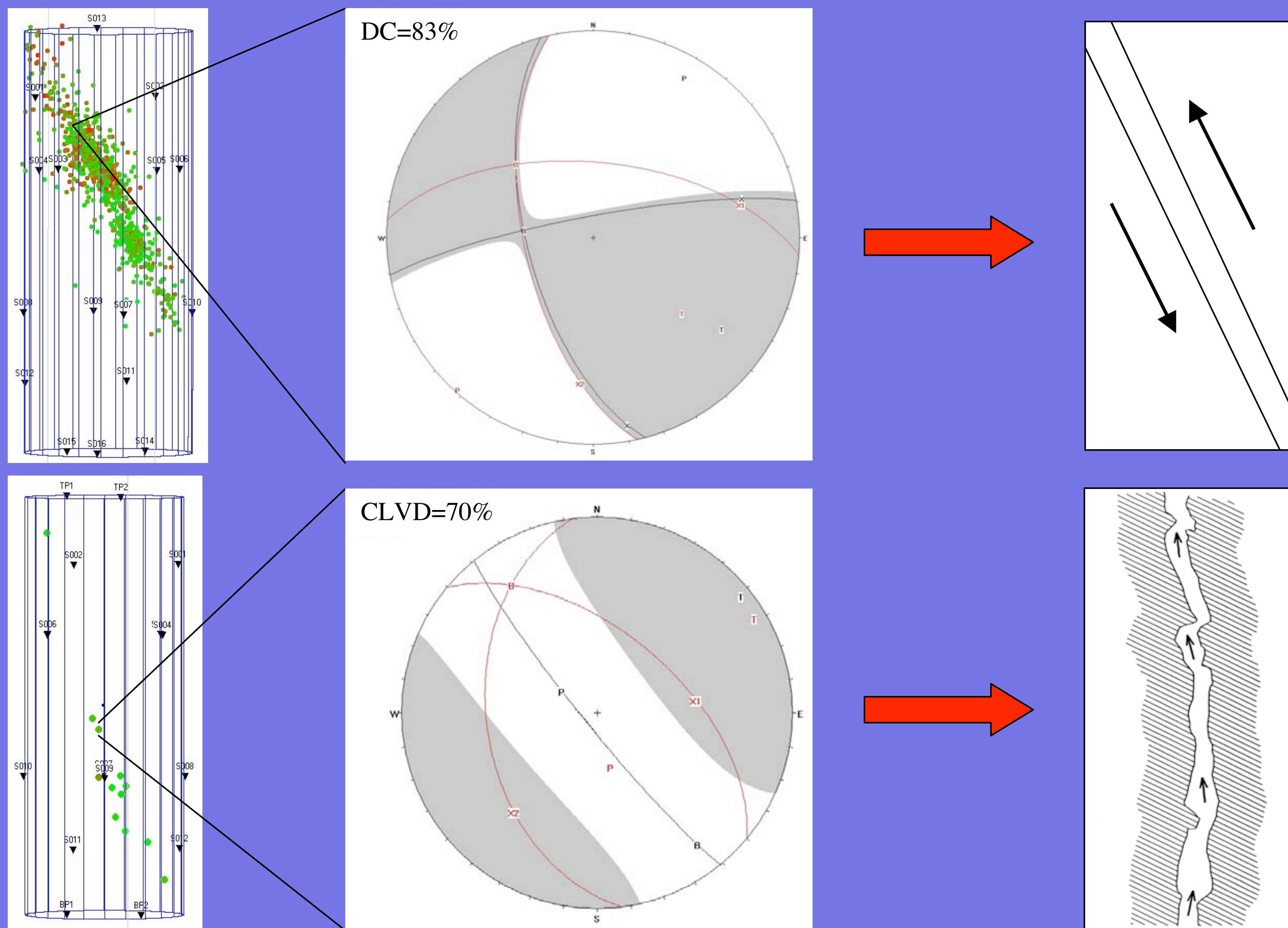


P.M. Benson, Euro-Conference, Erice, 2007

Conclusions

What have we done?

- **Imaged fracture nucleation and rupture in natural Etnean basalt via AE location**

What have we shown?

- **AEs from fracturing have a markedly monochromatic spectrum, just like low frequency volcanic earthquakes**
- **How simple pore decompressions can produce waveforms that (qualitatively) share features with field seismicity.**
- **Locations of these decompression events match the fault plane, and preliminary work suggests a high component of CLVD mechanisms: indicative of fluid movement**
- **We postulate that 'hybrid' events evolve after pore decompressions start, when cracks come into contact**

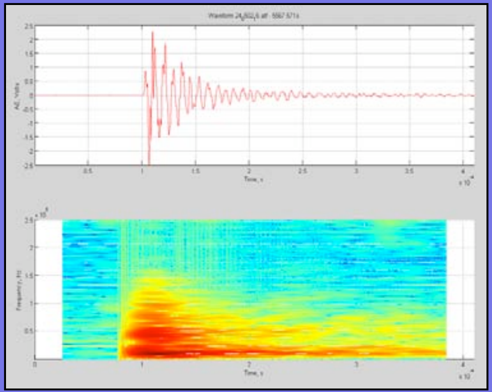
The future…

- **Analysis of decompression events in terms of mechanisms**
- **Scaling of events via frequency/magnitude analysis**
- **Experiments at elevated temperatures**

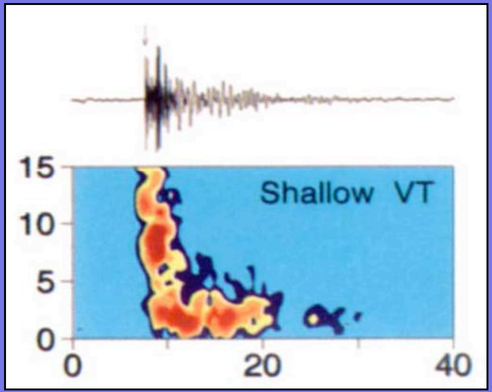
Discussion of results: frequencies

Frequency scaling offers the best way to assess the similarity of the physical processes between laboratory experiments and natural volcanic seismic signals (Burlini et al., 2007, Geology):

- Lab low frequency AE and tremor have: f_1 = 0.1-2 MHz
- Lab fracture lengths are in the range: d_1 = 0.1 – 20 mm
- Natural low frequency EQs have: f_2 = 1 – 2 Hz
- Associated fracture lengths are in the range: d_2 = 100 m – 1 km



Lab. Field



Dominant frequency of EQs scales inversely with source dimension:

- Hence we can write: $d_1 \times f_1 = d_2 \times f_2$
- Using the above data, we find: $d_2/d_1 = 0.05 – 10 \times 10^6$

  and: $f_1/f_2 = 0.1 – 20 \times 10^6$

This indicates good agreement between natural and lab observations